OAR:
The Basic Research Agency
of The United States Air Force

VOLUME II NUMBER 4 25 MARCH 1963

PROPERTY OF
AFL LIBRARY
3 APR 1963
USAF ACADEMY

ION TITRATION

JEAN H. FUTRELL, Chemistry Research Laboratory (ARL)

Titration is the process whereby the quantity of a chemical species is estimated by observing the volume or mass of some reagent which it will consume in a chemical reaction. The simple acid-base titration is one of the first demonstration experiments performed in freshman chemistry. We have recently provided a new wrinkle in this old established procedure by performing quantitative titration of ions in the gas phase. In our system the approach of an end point is not indicated by color change or by a p-H meter but rather by the quenching of a chemical reaction. The end product of our experiment is not a value for acidity or basicity of a solution, but rather a set of rate constants for certain ion-molecule reactions in the gas phase.

In an earlier issue of the OAR bulletin we discussed the sensitized radiolysis of propane by means of rare gas ions. In the present work we have concerned ourselves with the sensitization reaction involving argon. Under our kinetic conditions it is known that the principal primary reaction of argon produced by ionizing radiation is simply the act of forming argon ions. By usual methods of chemical kinetics, we follow the decomposition of propane due to dissociative charge exchange reaction with argon ions produced by a 1 Mev electron beam. It is known from mass spectrometer studies that molecular hydrogen reacts extremely efficiently with argon ions at low pressures and the reaction cross section or rate constant for this reaction is known. Thus the addition of hydrogen to the argon, propane, scavenger system results in a competition between propane molecules and additive molecules for the argon ions formed in the primary step. Experimentally we have observed an exponential quenching of the sensitized radiolysis reaction as successively larger amounts of hydrogen are added to the system.

We may illustrate more specifically the object of this investigation by considering the chemical reactions

$$Ar^+ + C_3H_8 \xrightarrow{(1)} \text{Disappearance of Propane}$$

$$Ar^+ + H_2 \xrightarrow{(2)} ArH^+ + H$$

Reaction (2) is faster than reaction (1), so addition of moderate amounts of hydrogen quantitatively removes Ar^+ from the system and quenches the sensitized radiolysis. Since the rate constant k_2 is known, a "titration" study in the concentration region where competition between these reactions occurs permits the calculation of a value for k_1.

Kinetically the system is a bit more complicated than we have described it and it is necessary also to consider sensitization of radiolysis by hydrogen ions and the reaction of hydrogen ions with argon as the concentration of hydrogen is increased. These reactions complicate the final differential equations representing the steady state kinetics without changing any of the principles involved. Since the rate constants for the reactions involving hydrogen and argon have been measured, it is possible to take these numbers and the present data and evaluate the rate constants for the reactions of both argon ions and hydrogen molecule ions with propane. For these we have obtained the values $K_{ar} = 2.3 \times 10^{12}$ liter/mole-sec. $K_{h_2}+ = 2.5 \times 10^{13}$ liter/mole-sec. Both of these rate constants are very large when compared to rate constants for ordinary free radical reactions and are enormous in comparison to more conventional chemical reactions. For example, the abstraction reactions of methyl radical in methane (considered a "fast" reaction), which has been recently measured, is 7.8×10^8 liter/mole-sec. Nevertheless, there is a fair amount of supporting evidence to indicate that rate constants of this magnitude for elementary processes such as dissociative charge exchange are not unreasonable. We can anticipate that chemical science will become familiar with such very fast reactions as probe further into high energy systems.

AIRBORNE SURVEY OF SOIL CONDITIONS

CARLTON MOLINEUX
Terrestrial Sciences Laboratory (AFCRL)

By a simple airborne radar survey, it may be possible to tell whether drylake beds, beaches, and other broad flat areas are sufficiently firm to support heavy aircraft. This is one of the goals of a cooperative AFCRL-Army Corps of Engineers project involving radar reflectivity characteristics from known soil samples. Soil conditions -- structure, composition, density, and moisture content -- are being correlated with such factors as radar wave length, polarization, and aspect angle.

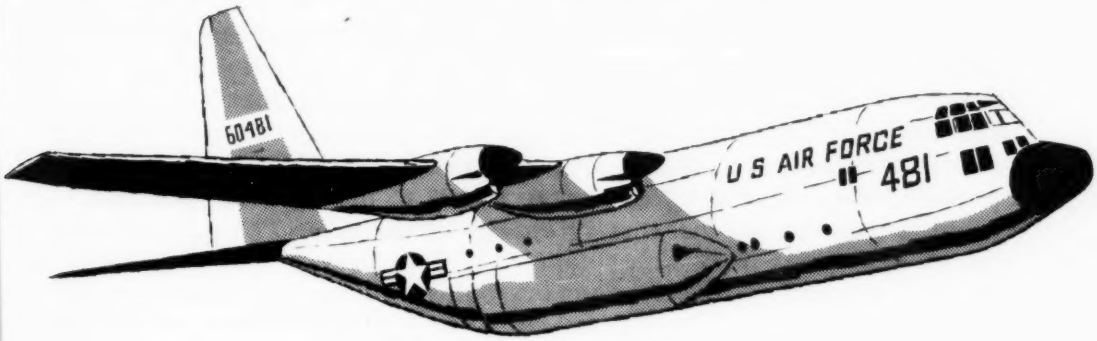
The tests are being conducted in Vicksburg, Mississippi, under an Army Corps of Engineers contract. A high wooden arch structure,

standing some 50 feet high (and 50 feet across at the base) is being used. The soil samples are placed in large carts on the floor of this large half-cylinder structure. To measure the radar reflectivity characteristics from all aspect angles, the radar antennas are mounted on a carriage which travels along the inside of the arch, permitting measurements to be made at all angles from 30 to 90 degrees.

A variety of soil samples are placed under the arch for measurements of their reflective properties at various frequencies and from various angles. The bistatic pulsed radar system used covers the Ka, X, C and P bands. Deep penetration of wet soils is afforded by P-band. The other three bands permit analysis of relatively dry soils. Present testing is being made on natural soils of known characteristics. In the future, vegetation-covered and frozen soil samples will be tested also.

Following the laboratory testing program, the radar system will be installed in a light aircraft for validation flights over known areas. Eventually, the terrain analysis radar system will be installed in an AFCRL C-130 aircraft for reconnaissance of terrain properties of remote areas difficult for ground party exploration.

The program has immediate military application in determining terrain properties which affect aircraft or surface vehicle mobility. In the future the system might be applied to remote measurement and mapping of lunar and planetary surface material conditions.



what is the structure of the NUCLEUS?

CAPTAIN ALBERT W. HARRISON, JR., Nuclear Physics Division (AFOSR)

The answer to the title question has intrigued and eluded man since Lenard in 1903, and Rutherford in 1911, first suggested and effectively demonstrated the existence of the nucleus.

Many answers have been proposed, some based on experiment and some on intuition, but most have failed by virtue of their inability to adequately predict, or account for, new experimental data. In truth, all of the theories, or models, of nuclear structure proposed to date have failed to the degree that there is no single model which can properly predict or explain all experimental results. An experiment being conducted by Professor H. Anderson and Professor H. Tyren at the Enrico Fermi Institute for Nuclear Studies of the University of Chicago, supported by AFOSR, has recently shown great promise in serving as a crucial test of the various possible theories of nuclear structure.

This experiment was conceived and originally attempted at the University of Uppsala, Uppsala, Sweden by Professor H. Tyren and collaborators. Briefly, the experiment consists of bombarding a nucleus with a proton beam of known energy and subsequently detecting and determining the energy of two emerging protons which had interacted, one from the beam, and one from the nucleus. The difference between the sum of the energies of the two detected protons and the original energy of the incident proton, corrected for the energy lost in the recoil of the residual nucleus, is then a measure of the binding energy of the proton removed from the nucleus.

The basic requirements for success of the experiment are:

1. The incident proton reacts with only one proton in the nucleus, otherwise the binding energy would be in error. This is done by using the optimum incident proton energy and by coinci-

dence detection of the emerging protons.

2. Accidental coincidences must be reduced to a minimum.

3. The energy determination of the emerging coincident protons must be precise enough so that the error is small compared to the binding energy being determined.

4. At the time of the interaction in the nucleus, the nucleon-nucleon forces do not affect the interaction to any large degree. This is what is meant by "quasi-free proton-proton scattering". If there were no nucleon-nucleon forces involved, it would be free proton-proton scattering. The original experiment at Uppsala, with 185 Mev incident protons, did not adequately meet these requirements, but was successful enough to demonstrate the feasibility of the approach. Concurrent theoretical considerations verified that conclusion.

Upon mutual agreement, it was decided to attempt the experiment at the 450 Mev Synchrocyclotron at the Enrico Fermi Institute. The velocity attained by the incident protons at 450 Mev is such that, for the lighter elements, the proton transit time through the nucleus is sufficiently reduced so that a much more favorable ratio of single to multiple interactions is obtained. At energies higher than 450 Mev, the resulting meson production is as undesirable as the more probable multiple interactions at the lower energy. A peripheral magnet was added to the accelerator to improve the proton beam. In normal operation, the synchrocyclotron beam consists of a series of bursts of protons. In other words, the number of protons per unit time is not constant (for times much less than a second), but varies from very large to very small numbers. Consequently, the experimental observation time is restricted to those periods when the bursts strike the target. Not only does this increase the operating time required to acquire adequate statistics, but the large number of protons in a given burst causes an unacceptably large number of accidental coincidences in the detection system. The manner in which the peripheral magnet was operated effectively spread out each burst of protons in time (it is called a "beam stretcher"), increasing the experimental observation time per burst and reducing the accidental coincidences to an insignificant level. Two precicion, double focusing, magnetic spectrometers were constructed to accept the emerging protons. They are placed at equal (variable) laboratory angles to the left and right of the incident proton beam

direction and are able to analyze protons up to about 250 Mev with a resolution of about 1 Mev. In each spectrometer the protons are actually detected by four momentum channels each consisting of two scintillators in coincidence, the second scintillator being common to all four channels. Since the reaction is only "quasi-free", a correction is required to account for this departure from "free" scattering. This correction is made by using distorted wave calculations in the computer analysis of the results.

The preliminary results were reported to the International Symposium on Direct Interactions and Nuclear Reaction Mechanisms held at the University of Padova, Italy, in early September 1962. These results revealed the details of nuclear structure in an unusually clear way. The equipment operated so well that discrete groups of protons were observed in the light nuclei used as targets, and the total resolution ($\pm$ 3 Mev) is such that it should be possible to obtain information on the momentum distribution of the proton groups in the nucleus via angular correlation analysis.

The full significance of the experiment must await extensive mathematical analysis. Further results will be reported as they emerge.

COMPUTER I.Q. TESTS

DR. HANS H. ZSCHIRNT, Computer and Mathematical Sciences Laboratory (AFCRL)

All those who have taken aptitude or general intelligence tests have been faced with the so-called geometric-analogy type of question -- that is, questions which read, "Figure A is to figure B as figure C is to which of the following?" Several geometric figures then follow from which the test subject must make a choice. Such questions are designed to test human problem-solving ability and decision-making ability since much of the human decision-making process involves analogy.

The geometric-analogy problems also lend themselves to computer solution. But as is the case whenever the computer is used

for problem-solving, the key requirement is the development of an appropriate program. Currently under study by Thomas Evans of AFCRL is the design of such a program that will permit us to test the computer's ability to solve geometric-analogy test problems.

Using a program written by Evans, the computer has already solved many problems taken from college entrance examinations. At the present time, rather primitive coded descriptions are used that simulate the output of an input reading device. The program is written in LISP, a list processing language developed at MIT for the IBM 7090, and which is now being translated for use on its RDE (Research Data Evaluator) computer.

The elements in the process seem to go beyond conventional pattern classification and recognition techniques since they involve the classification of elements into classes with (so to speak) floating boundaries. Essentially, the present program consists of two main parts. The first part is concerned with the description of the figures themselves, a process which involves breaking each figure down into its distinctive elements. The second part is concerned with the actual solution of the problem. Using the descriptions of the figures, the computer attempts to find the particular relationships existing between figures A. and B. It then applies the rules that it has evolved to discern figure C's relationship to one of the unknown answer figures.

The program used is heuristic, as are many problem-solving programs. It quickly examines, or questions, a wide range of possible solutions, in order to arrive at a narrow set of possibilities that can be handled more easily.

The development of programs to solve I. Q. test problems is not, of course, a goal in itself. Geometric-analogy programs, as in the case of other AFCRL research projects that involved bridge and chess games, furnish a convenient mechanism for evolving effective programming languages. These new and powerful languages, which have assumed a greatly increased role in computer research during recent years, have already greatly expanded the versatility and effectiveness of computers.

that they who RUN may READ

DR. HAROLD WOOSTER
Information Sciences
Directorate (AFOSR)

Given a stack of documents and asked questions about the contents of the documents one might tend, the first time around, to scan the pages of the documents looking for familiar and relevant words. As soon as time permitted one might try to get the store in a little better order, either by making abstracts and searching the abstracts or building up an index either to the abstracts or to the pages of the documents. The decision as to when to stop reading every page and start building up abstracts and indexes would depend upon such variables as the size of the pile, the reading speed of the searcher, and the number of questions that are asked. If one could read every page more or less instantaneously, there might be no need to worry about indexes.

This is somewhat the problem faced by the information system designer who faces the problem of how to use a computer in literature searching. Assuming that the text is available in machine-readable form (and this is not a trivial assumption--many years and many more millions of dollars have been invested in the search for a practical character reader) what should be the next step; to scan unedited text for the presence of exactly specified words?; to automatically prepare a concordance for human or machine searching, storing both the original text and a list of major words, with reference to appropriate passages in the text?; or to transform the original texts into "abstracts" or "sets of index terms" and search these in response to a query?

Some answers to these questions were obtained in a recently completed study carried out for the Directorate of Information Sciences, AFOSR, by a research team at the Thomas J. Watson

Research Center, International Business Machines under contract AF 49(638)-1062, and reported in AFOSR-2817, authored by Dr. Manfred Kochen, aided by C. T. Abraham, E. Wong and H. G. Bohnert.

The original proposal provided for using the sophisticated table look-up techniques developed at IBM with the support of Rome Air Development Center in connection with mechanical translation of Russian to scan a record of abstracts formed automatically from raw text by means of a frequency based sentence ranking technique. (This method, originally devised by H. P. Luhn, forms an extract of document by picking those sentences which contain "unusual" words, as compared to the normal distribution of words in scientific English as being those most characteristic of the way in which a particular paper differs from all others).

Two facts soon became evident:

1. A simple perusal system based on the Luhn word-counting techniques can be made to work right now.

2. Any attempt to do anything more elaborate to text than simply pulling out relevant sentences faces deep logical-linguistic problems rather than mathematical-statistical ones.

Work under the contract indicates that machine perusal of English texts in response to certain kinds of queries is possible, and established some steps and findings towards its practical implementation.

For example, important new formulas were derived for the average time to search both an ordered file of descriptor-words, such as an alphabetized index in contrast to the words in random order, as they would occur in running text. These relate the mean search time to such parameters of the file as the average number of items per index term and such parameters of the question as the number of clauses joined by "or's", and the number of descriptor words in each clause joined by "and's" and "and not's". For an unordered file, as occurs when raw text is searched, the mean search time varies roughly as the square of the mean number of documents per "index" term. As the number of descriptor words in each of the clauses joined by "and's" increases,

the mean search time also increases, but a decreasing rate, until it levels off to a constant. The mean search time is directly proprotional to the number of alternative clauses in the query that are joined by "or's". ("Or" searches take care of synonms--"radar" or "radio detecting and ranging apparatus" and are particularly important when dealing with raw text; "and" searches narrow the field of inquiry--"Infra-red and detection and not cooking".)

Searching indexes by computer is only half of the job; the other half is to mechanically convert raw text into such indexes or transforms. Word counting techniques are available and work. It is much more difficult, and less superficial, to try to group related texts together on the basis of logical similarities in their contents and then represent each text in such a group by means of the words or sentences they have in common.

To detect that two texts, or a text and a question logically, relate to the same subject matter, both must be translated into a standard language that can be machine processed. The first three in a hierarchy of such formal languages were constructed. Sentences in the higher language resemble a rather formal English; those in the lower level languages resemble an applied predicate calculus (speaking very loosely indeed, something like symbolic logic).

Computer rules for transforming sentences from higher-level to lower-level languages were found (with the help of some of the language processing techniques developed for machine translation) and for recognizing sentences in a language of a given level. Phrases like "every missile", "any part", "an executive", "some weapon", "no missile" were found to act syntactically like simple English names.

It seems at least possible that questions can be asked in terms of the English-like sentences of these higher-level formal languages, and that some, though certainly not all of the sentences of the texts to be scanned can be translated in this way. These and other techniques should make it possible eventually to determine the logical equivalents of certain pairs of linguistic units (sentences, phrases and words), to group documents on the basis of logical pertinence

to the same subject, and to transform documents to facilitate search in a more significant way than by merely counting and matching linguistic units as they occur.

To demonstrate that useful, unsophisticated document scanning is possible with a 7090 computer integrated with a photostore (a high density rapid access storage device developed for mechanical translation and consisting essentially of a rotating disk coated with photographic emulsion which stores information as bit patterns on concentric tracks), a system for automatically transforming texts based on table-lookup-language-processing techniques has been implemented to the point where the major computer programs involved have been tested or are under test. The system consists of an English stem dictionary in the photostore, and of 7090 programs based on two novel mathematical-statistical methods for constructing "abstracts" and index units: Tanimoto's words or sentence-ranking method and an original word or sentence "clustering" technique.

The authors conclude: "Such frequency based 'counting' techniques impose serious limitations on the quality of perusal, or on the extent to which genuine abstracts can be formed. On the whole it appears that unsophisticated, high-speed perusal would be practical and useful in the near future. Automatic high-quality perusal, which is probably not in as urgent and wide demand (for the price it would require as low-quality perusal (which can be made high-quality by human aid), and it must await major, unpredictable results in long-range, basic research."

REFERENCE:

"High-Speed Document Perusal", Final Technical Report under Contract AF 49 (638)-1062, containing as Appendices:

a. AFOSR-TN-61-1, "A Sampling Procedure for Clustering Similar Documents", by C. T. Abraham.

b. AFOSR-TN-61-2, "Time Estimation in Boolean Index Searching", by E. Wong.

c. AFOSR-TN-62-3, "An English-Like Extension of an Applied Predicate Calculus", by H. G. Bohnert.

the ENERGY BAND STRUCTURE of TELLURIUM

LT. COLONEL RALPH W. CONNERS, Solid State Sciences Division (AFOSR)

An investigation that was conducted by Dr. Allen Nussbaum Honeywell Research Center, Hopkins, Minnesota, under AFOSR sponsorship, concerned the element tellurium. Tellurium is a semiconducting element which lies in column VIA of the Periodic Table. Other members of this column are the insulators oxygen and sulfur, the semiconductor selenium, and the metallic element polonium. Tellurium does exhibit allotropism, but our concern here is purely with the semiconducting modification. Relatively few practical applications have been found for tellurium at the present time, but its properties as a semiconductor have been studied in a number of laboratories as a result of interest in the striking atom arrangement found in the tellurium crystal. See Figures 1A and 1B. One of the objectives of the program was the determination of the energy band structure of tellurium from a knowledge of the crystal symmetry and the comparison of this structure with experimental results. It was found from galvanomagnetic data that the salient features of this structure are the existence of a single conduction band and a double, overlapping valence band. Each of these three bands contains six ellipsoids at equivalent interior points of the first Brillouin zone. In Fig. 2 is shown the first Brillouin zone. The nature of the arrange-

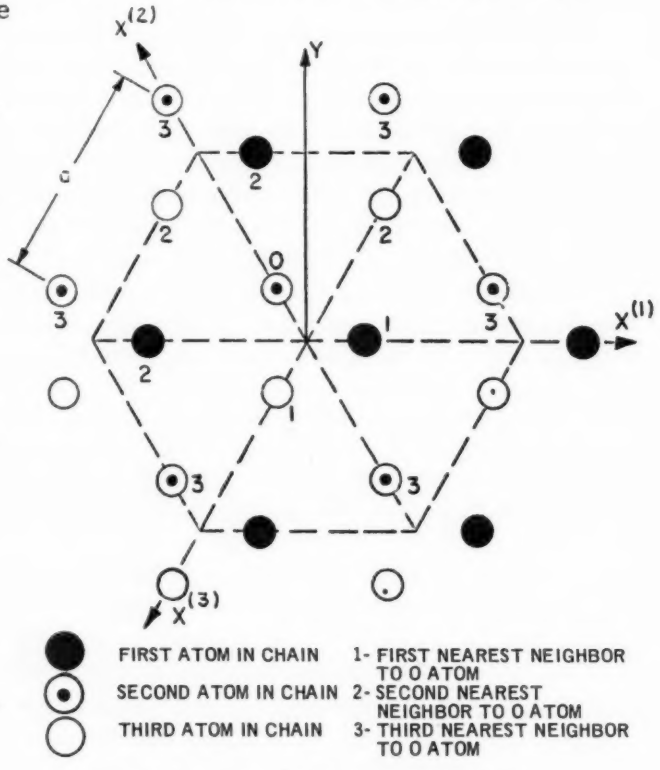


Figure 1A - Crystal structure of tellurium (trigonal screw axis along OZ)

ment of these ellipsoids is shown in Fig. 3 and this symmetry is the lowest one possible for interior ellipsoids.

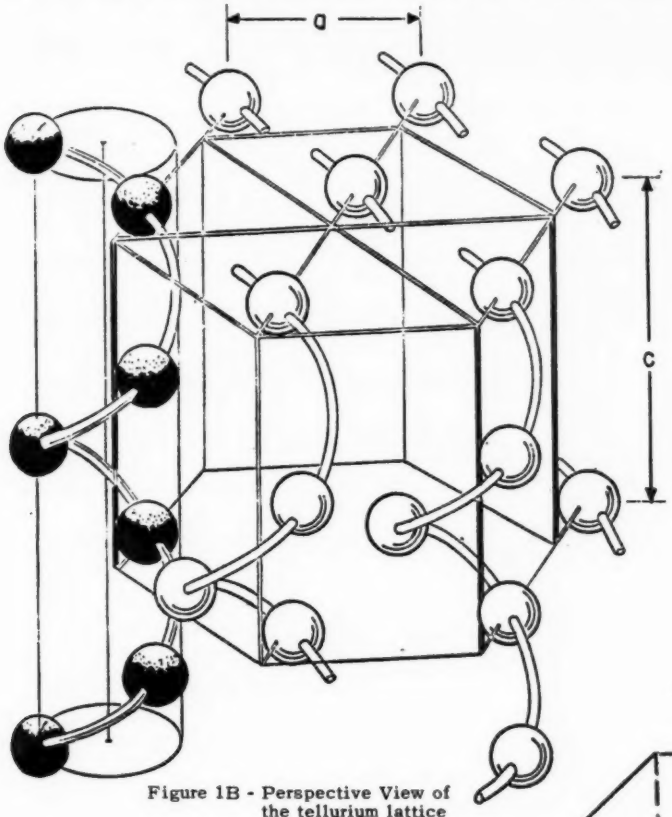


Figure 1B - Perspective View of the tellurium lattice

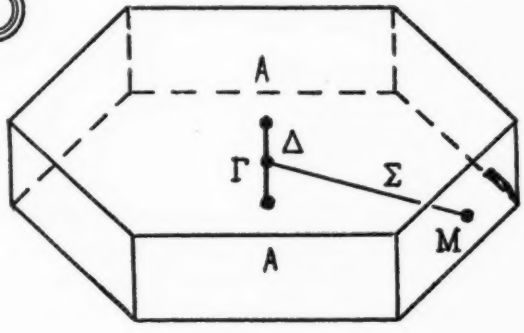


Figure 2 - Brillouin zone for tellurium

The energy band structure proposed by Nussbaum is called the six-ellipsoid model, in contrast to the twelve-ellipsoid model proposed by Rigaux, which is illustrated in Figure 4. The following relationship taken from this reference,

$$6\overset{\frown}{1111} - 2\overset{\frown}{1122} = 2\overset{\frown}{1313} + 3\overset{\frown}{3333}$$

can be compared to the corresponding formula for the six-ellipsoid model,

$$3\overset{\frown}{1111} - \overset{\frown}{1122} = \overset{\frown}{3333}$$

which has been previously shown to be valid to within a factor of 2 to 5 when compared to experimental results at 4.2°K, where single-carrier expressions are valid. A similar comparison for the Rigaux formula gives agreement to within a factor of 3, so that at this time it is not possible to differentiate between the six-ellipsoid and the twelve-ellipsoid models, either of which is consistent with inherent symmetry.

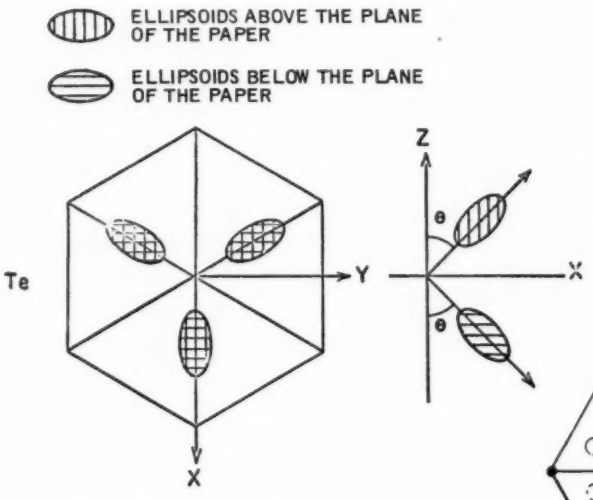


Figure 3 - Ellipsoid arrangement (six-ellipsoid model)

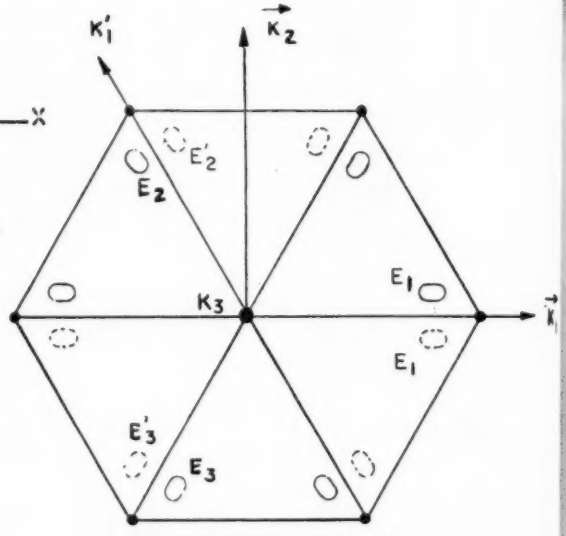


Figure 4 - The twelve-ellipsoid model of Rigaux

On the basis of experiments performed on large, Bridgman-type crystals, Rigaux concludes that the valence band is single and the conduction band is double, whereas Nussbaum proposes the opposite structure. The evidence for a double valence band is based on the behavior of the Hall coefficient at the upper reversal temperature and the existence of the 11 - micron absorption band.

Finally, it should be mentioned that the previous band structures determined by Callen, Reitz and Asendorf, all of which show extrema at the point A in the Brillouin zone, are not in accord with the experimental evidence which has been gathered during the course of Nussbaum's investigation.

NOTICE TO OUR READERS

Requests for further information should be directed to the individual or laboratory of origin.

Addresses are as follows:

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
Attn: CRI
Laurence G. Hanscom Field, Bedford, Massachusetts

AERONAUTICAL RESEARCH LABORATORIES
Attn: ARB
Wright-Patterson Air Force Base, Ohio

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Attn: SRIL
Tempo D Building
4th and Independence Avenue, S.W., Washington 25, D. C.

OFFICE OF RESEARCH ANALYSIS
Attn: RRR
Holloman AF Base, New Mexico

Detailed documentary reports may be obtained from:

OFFICE OF TECHNICAL SERVICES
U.S. Department of Commerce, Washington 25, D. C.

ARMED SERVICES TECHNICAL INFORMATION AGENCY*
Arlington Hall Station, Arlington 12, Virginia
* Qualified requestors

RESEARCH REVIEW is published by the Office of Information (RREI), Office of Aerospace Research, USAF, Washington 25, D. C. The frequency of this publication is determined solely on the basis of the availability of significant material to report. The objective is to make a positive contribution to the exchange of information about Air Force sponsored and conducted basic research activities. Individuals or groups associated with basic research may obtain copies by written request to the above address.

GPO 941227